Cellular Networks

- **Base stations** transmit to and receive from mobile devices at the assigned spectrum
  - Multiple base stations use the same spectrum (**spectral reuse**)
- The service area of each base station is called a **cell**
- Each mobile terminal is typically served by the ‘closest’ base stations
  - **Handoff** when terminals move
It is useful to think of a cellular network in terms of generations:

- **0G**: Briefcase-size mobile radio telephones
- **1G**: Analog cellular telephony
- **2G**: Digital cellular telephony
- **3G**: *High-speed* digital cellular telephony (including *video telephony*)
- **4G**: IP-based “anytime, anywhere” voice, data, and multimedia telephony at *faster* data rates than 3G
GSM (2G)

- Abbreviation for Global System for Mobile Communications
- Concurrent development in USA and Europe in the 1980s
- The European system was called GSM and deployed in the early 1990s
- Voice, 3.1 kHz
- Short Message Service (SMS)
  - 1985 GSM standard that allows messages of at most 160 chars. to be sent between handsets and other stations
  - Multi-billion $ industry

GSM Frequencies

- Originally designed on 900MHz range, now also available on 800MHz, 1800MHz and 1900 MHz ranges.
- **Separate uplink and downlink frequencies**
  - One example channel on the 1800 MHz frequency band, where RF carriers are spaced every 200 kHz
Mobile Station (MS)

- MS is the user’s handset and has two parts
- Mobile device
  - Equipment **IMEI** (Intl. Mobile Equipment Identity)
- Subscriber Identity Module (SIM)
  - Subscriber **IMSI** (Intl. Mobile Subscriber Identity)
    - 64 bit number; includes:
      - MCC (Mobile Country Code): 3 decimal places, intl. standardized
      - MNC (Mobile Network Code): 2 decimal places, network within country
      - MSIN (Mobile Subscriber Identification Number): max. 10 decimal places

5G Challenges & Scenarios

- Avalanche of Traffic Volume
  - Further expansion of mobile broadband
  - Additional traffic due to communicating machines
  - “1000x in ten years”

- Massive growth in Connected Devices
  - “Communicating machines”
  - “50 billion devices in 2020”

- Large diversity of Use cases & Requirements
  - Device-to-Device Communications
  - Car-to-Car Comm.
  - New requirements and characteristics due to communicating machines
5G Technologies

- Massive MIMO
  - Dramatically increase number of antenna elements on base station

- Ultra-Dense Networks
  - Substantially reduce cell sizes to handle more users

- 5G Waveforms
  - Improve bandwidth utilization through signal structure improvements such as NOMA, GFDM, FBMC, and UFMC

- mmWave
  - Utilize potential of extremely wide bandwidths at frequency ranges once thought impractical for commercial wireless

Summary

<table>
<thead>
<tr>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
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<tbody>
<tr>
<td>2 Kbps</td>
<td>64 Kbps</td>
<td>2 Mbps</td>
<td>100 Mbps</td>
<td>10 Gbps</td>
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</table>

- 1G: Basic voice service using analog protocols
- 2G: Designed primarily for voice using the digital standards (GSM/CDMA)
- 3G: First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)
- 4G: True mobile broadband on a unified standard (LTE)
- 5G: “Tactile Internet” with service-aware devices and fiber-like speeds
Cloud Computing

• “Cloud computing is a model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” [NIST.GOV]

• “Pay-per-use” where relevant (differs from “hosted” environments, where model is “pay for maximum capacity”)

• Treats IT more as a utility than as a capital expense that must be managed and upgraded

Cloud Computing Delivery Models

New Pizza as a Service
Cloud Computing Delivery Models

- **Software-as-a-Service (SaaS):** an application environment is provided
- **Platform-as-a-Service (PaaS):** an application development platform is provided
- **Infrastructure-as-a-Service (IaaS):** infrastructure capabilities (such as storage or a bare operating system) are provided
Cloud Computing Delivery Models

- IaaS
  - Amazon EC2
  - DigitalOcean
  - Rackspace

- PaaS
  - MongoDB
  - Salesforce
  - Skylight

- BaaS
  - Firebase
  - Skygear
  - Parse Server

- SaaS
  - Zendesk
  - PayPal
  - Facebook

Mobile Apps & Cloud Computing

- Mobile Cloud Computing (MCC)
  - Infrastructure where both the data storage and data processing happen outside of the mobile device

- Mobile cloud applications move the computing power and data storage away from the mobile devices and into powerful and centralized computing platforms located in clouds, which are then accessed over the wireless connection based on a thin native client
Cloud Computing Delivery Models

- **Software-as-a-Service (SaaS):** an application environment is provided
- **Platform-as-a-Service (PaaS):** an application development platform is provided
- **Infrastructure-as-a-Service (IaaS):** infrastructure capabilities (such as storage or a bare operating system) are provided
- **Backend-as-a-Service (BaaS):** a cloud service model in which developers outsource all the behind-the-scenes aspects of a web or mobile application so that they only have to write and maintain the frontend (also MBaaS)

Mobile Cloud Computing – Why?

- Limited mobile resources
  - Battery, storage, processing, network, ...
  - Consider tradeoffs!

- Permanent storage
  - Backup (reliability), long-term storage, anywhere access (availability)

- Data sharing
  - Social media, sensor data, collaboration, producer-consumer, ...
Mobile Cloud Computing

- More resources
- Reliability and availability
- Sharing of data & information
- Control access of data
- MCC allows for dynamic provisioning
  - Resources always available; no need for reservation
  - Mobile applications can be scaled to meet user demands
  - Services can be added and expanded easily
  - Multiple services can be integrated through cloud
- New/additional services possible (or easier)
  - Mobile payment
  - Push notifications
  - Advertising
  - Analysis tools
  - Social network integration
  - User management tools

MBaaS – Focus on Frontend!
**MBaaS Providers**

- kinvey
- FeedHenry
- Amazon Web Services
- anypresence
- appcelerator
- apigee
- back4app
- Sancho
- Firebase
- TruJunction
- built.io
- Parse.com
- Google Cloud Platforms
- heroku
- Self-hosted

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**Example: Back4app (parse.com)**

- Founded in 2011
- Acquired by Facebook in 2013
- More than 500,000 apps in 2014
- Shut down January 2017
- Made code open-source
- Many replacements, including self-hosted
- Back4app.com
Back4app

- [www.back4app.com](http://www.back4app.com)
- iOS: [http://docs.back4app.com/docs/ios/](http://docs.back4app.com/docs/ios/)
- Android: [http://docs.back4app.com/docs/android/](http://docs.back4app.com/docs/android/)
- Cloud Code: [http://docs.back4app.com/docs/integrations/](http://docs.back4app.com/docs/integrations/)

Parse/Back4app Dashboard
Firebase

• Yet another Backend as a Service (BaaS):
  – "Firebase is a real-time cloud data service. Firebase database is stored as JSON and synchronized in real time to every connected client. When you build cross-platform apps with our Android, iOS, and JavaScript SDKs, all of your clients share one Firebase database and automatically receive updates with the newest data”

• Designed for web and mobile
• Founded in 2011
• Initial product was backend so websites could easily host chat as part of site
• Discovered developers were sending non chat data (such as game state) via the tool

Firebase

• Create Firebase project in console
• Just needs name and country
Firebase

• After creating project, overview page:

  ![Firebase Overview](image_url)

Firebase

Add Firebase to your Android app

1. Enter app details
2. Copy config file
3. Add to build.gradle

- Package name: examples.scottm.hellofirebase

Firebase

• After providing package name and SHA-1 fingerprint ...
• Firebase generates a JSON file named google-services.json specific for this project
  – multiple projects / apps -> repeat steps
• Download and add file to project
• Update gradle file

Firebase

• Documentation:
  • [https://firebase.google.com/docs/?authuser=0](https://firebase.google.com/docs/?authuser=0)

• Capabilities:
  – User authorization
  – Database storage
  – Storage for larger files
  – Cloud messaging
  – Push notifications
  – Analytics
  – Hosting of web content
  – ...
<table>
<thead>
<tr>
<th>Alternatives</th>
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<tr>
<td><img src="https://github.com/relatedcode/ParseAlternatives" alt="GitHub Repository" /></td>
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</tbody>
</table>

**Alternatives**

- [https://github.com/relatedcode/ParseAlternatives](https://github.com/relatedcode/ParseAlternatives)
Choosing a MBaaS

• Ease of Use (Parse, Back4app)
• Automated updates (Firebase)
• Analytics (User data, crashes)
• Authentication (including social media integration)
• App/Database management
• Push notifications
• Cloud code, background jobs
• System emails (password reset, verification)
• Variety of APIs (iOS, Android, REST)

Cloud Computing: Microsoft Azure

• Comprehensive set of cloud services (IaaS/PaaS)
• On-demand services hosted on Microsoft Data Centers
Cloud Computing: Microsoft Azure

Azure Service Platform

Developer Experience
Use existing Skills and Tools

Internet
Pay-As-You-Go

Small
$0.12
Per service hour

Medium
$0.24
Per service hour

Large
$0.48
Per service hour

X-Large
$0.96
Per service hour

Unit of Compute defined
Equivalent compute capacity of a 1.6Ghz processor (on 64bit platform)

Small
1 x 1.6Ghz
(moderate IO)
1.75 GB memory
250 GB storage

Medium
2 x 1.6Ghz
(high IO)
3.5 GB memory
500 GB storage

Large
4 x 1.6Ghz
(high IO)
7.0 GB memory
1,000 GB storage

X-Large
8 x 1.6Ghz
(high IO)
14 GB memory
2,000 GB storage

Other Providers

- Amazon Web Services (AWS)
  - Amazon Simple Queue Service (SQS)
  - Elastic Compute Cloud (EC2)
  - Simple Storage Service (S3)
  - Many more...

- Google Cloud Platform
  - Compute Engine (IaaS)
  - Google App Engine (PaaS)
  - Cloud AI
  - Google BigQuery